COMPACT, LIGHTWEIGHT, SMART BATTERY CHARGER

Final Report
6 November 2003 through 19 August 2005
Contract Line Item No. 0003
Contract No. W15P7T-04-C-K604

26 October 2005

to:

US Army CECOM
Fort Monmouth, NJ

submitted by:

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14. ABSTRACT
A rugged, level-3 smart battery charger was developed and delivered to the Army. This compact, lightweight charger weighs 22.5 ounces and has a volume of 55 cubic inches. The charger accepts either a universal AC input or a 19-28 VDC input and charges at up to 18 V and 5 A. A daisy-chain capability is included, allowing up to 10 units to be connected to a single power outlet. The operating temperature range is –20 0C to +55 0C. Test units passed specified environmental tests including: altitude, humidity, thermal shock, vibration, loose cargo, and drop. Status and error indicators provide visual operating information, and a black-out feature provides on-off control of the indicators.

15. SUBJECT TERMS
Smart Battery, Land Warrior, Battery Charger, SMBus, Smart Charger, Lithium-ion Battery, Rechargeable Battery, Scalable Charger

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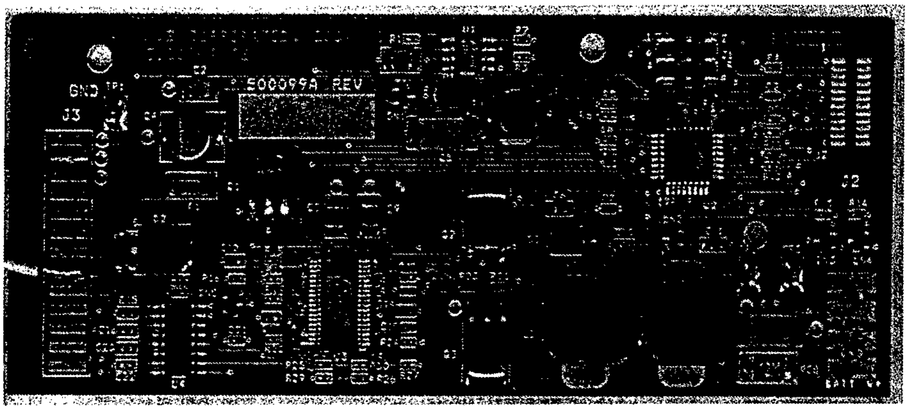


Figure 1. Top side of the 500099F_A PCB. The board measures 2" x 5", and has all surface-mount components – including surface-mount wire attachment points.

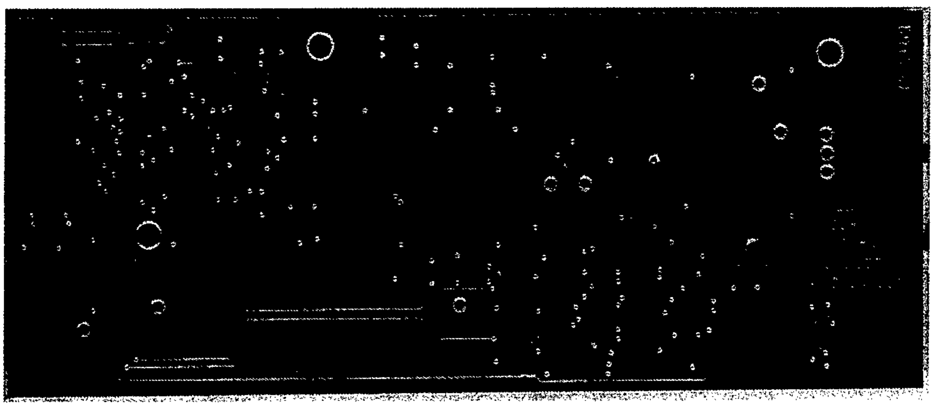


Figure 2. Bottom side of the 500099F_A PCB.

Additional testing of the charging circuit, using the 500099F_A design, indicated that the heat dissipation on the PCB was not enough to require heat-sinking of the PCB. Also, changes in the overall system design, including selection of the AC-DC converter, dictated a new form-factor for the charger's PCB. A redesign of the circuit and PCB included a PCB-mount, bulkhead connector, needed for the daisy-chain feature of the system, and placement of circuit components on both sides of the PCB. This new design, 500099F_B, is shown in Figs. 3 and 4. At 1.25" by 5", this B revision is less than two-thirds the size of the previous board.

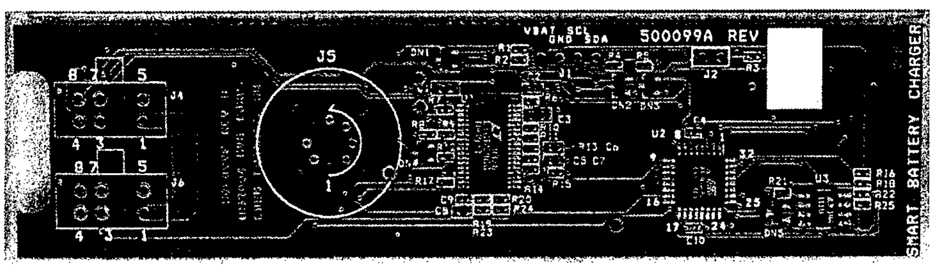


Figure 3. Top side of the 500099F_B PCB. Just to the left of center, is the footprint, J5, for the daisy-chain connector. Other through-hole footprints are for wire attachment.

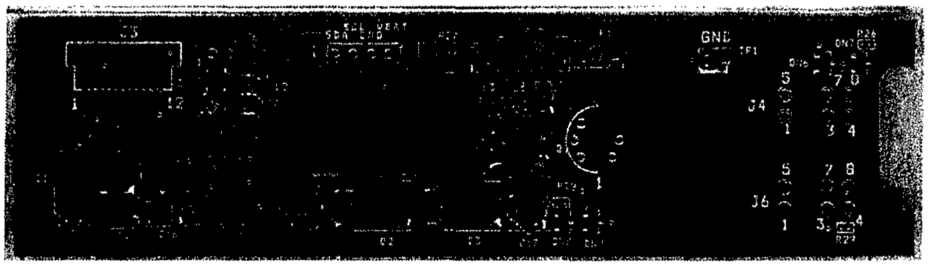


Figure 4. Bottom side of the 500099F_B PCB. As seen above, the power components – inductors, transistors, capacitors, and diode – for the charge circuit are on the bottom side of the board.

After initial testing of the Rev. B design, another change in the overall system design was required – initiating another revision of the charge circuitry and PCB. This final revision, 500099F_C, removed the bulkhead connector footprint from the design – to be replaced by a few through-hole wire connections – changed the physical outline somewhat, and placed all of the components on a single side of the board. The size of this board, like the B revision, is 1.25" by 5". This final revision is shown in Figs. 5 and 6.

Figure 5. Top side of the 500099F_C PCB.

Figure 6. Bottom side of the 500099F_C PCB

AC-DC CONVERTER

In order to meet the specified temperature requirements for the charger, i.e. an operating range of -20 ^{0}C to +55 ^{0}C, the AC-DC converter subsystem must also operate over this temperature range. In general, AC-DC converters are designed for indoor use, where the temperature range is relatively narrow, and is centered at roughly 25 ^{0}C. Thus, there are very few off-the-shelf converters that are specified over the temperature range required for the smart charger. In addition, most of the standard converters that are available require forced-air cooling when operated at elevated temperatures.

An AC-DC converter from N2Power was identified as the closest fit between a standard converter and the program design requirements. This converter was used in the Phase I demonstration, and preliminary (but limited) tests indicated that it would meet the program requirements. However, further testing, with the higher output current required in Phase II, showed that the temperature rise within the converter was unacceptable. Through the use of multiple thermocouples, the hold-up capacitor was identified as the primary limitation in the converter. In order to solve this problem, NVE developed a heat-sink collar for the capacitor. This collar provides a low thermal resistance path from the outside of the capacitor to the converter's primary heat-sink – as well as adding additional thermal mass and effectively increasing the surface area of the capacitor.

Based on the success of the heat-sink collar, NVE contracted with N2Power for the delivery of a custom AC-DC converter. In addition to including the capacitor heat-sink, the custom AC-DC converter were specified with a different hold-up capacitor that has a higher temperature rating, higher temperature rated transformers, different connectors, and different over-temperature behavior. For the over-temperature behavior, the converter will automatically cycle off and on as the internal temperature rises and falls. This is a safety feature that comes into play if the internal temperature rises above a preset threshold. The cycling behavior ensures that the system will automatically re-start when the temperature falls – the standard converter requires removal of input power in order to reset the device once an over-temperature event has occurred.

Figure 7 shows the complete, custom AC-DC converter. The circular hole in the top heat sink (filled with bright green) is above the hold-up capacitor. Because the heat-sink collar, that has been added to the hold-up capacitor, seals against the converter's main heat-sink, this hole was required as a safety vent for the hold-up capacitor. A view inside of the converter, in Fig. 8, shows part of the heat-sink collar around the hold-up capacitor.

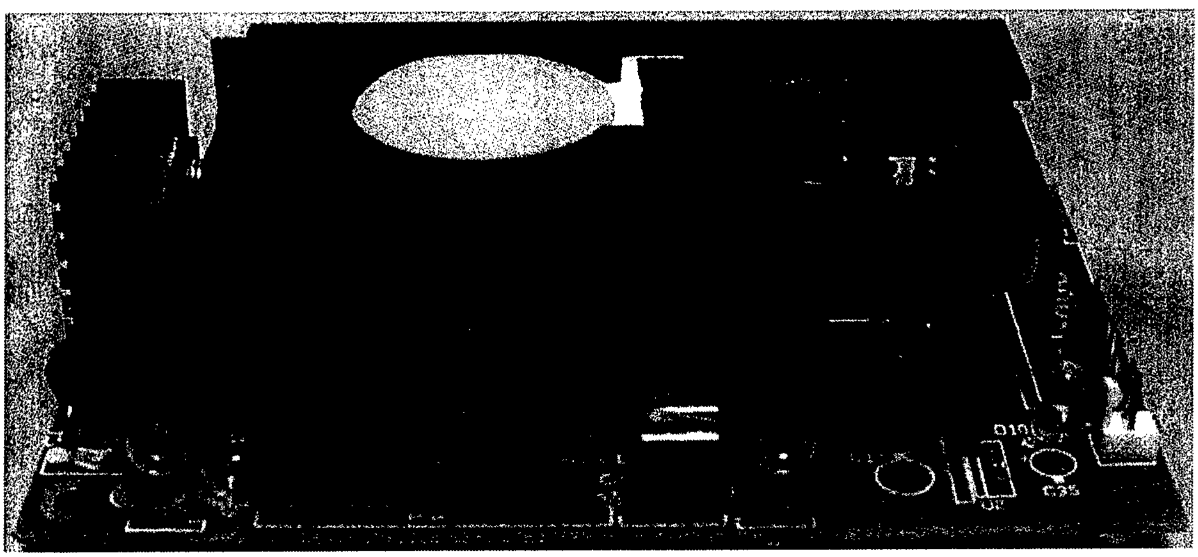


Figure 7. Custom AC-DC converter. This converter accepts a universal AC input and provides a 24 VDC output at up to 160 W.

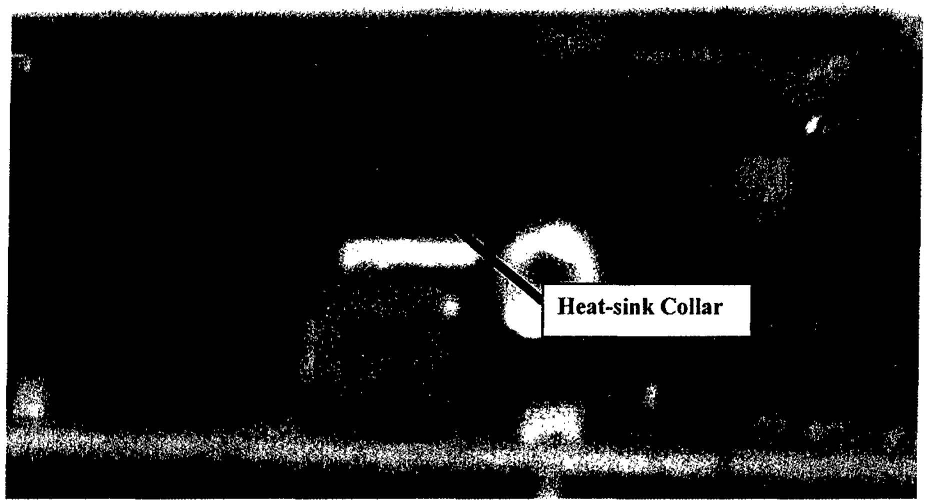


Figure 8. View inside the AC-DC converter. The shiny, silver-colored cylindrical object is the heat-sink collar that has been added around the hold-up capacitor.

CASE DESIGN

For the initial case design, an attempt was made to keep the form-factor of the case roughly the same as that of the LI-7 battery. With this design, the AC-DC converter heat-sink would be placed in thermal contact with one of the case's inside surfaces. The charger's PCB was placed next to the AC-DC converter, with a PCB-mounted bulkhead connector, for the daisy-chain function, helping to position the PCB and mount it to the case. In order to allow the unit to be serviced, and to simplify the case design and tooling, a screw-together design was used – rather than an ultrasonically welded design. Figure 9 shows an SLA model of the initial case design. The input and output cables have not been attached in this picture, but the rest of the charger has been assembled.

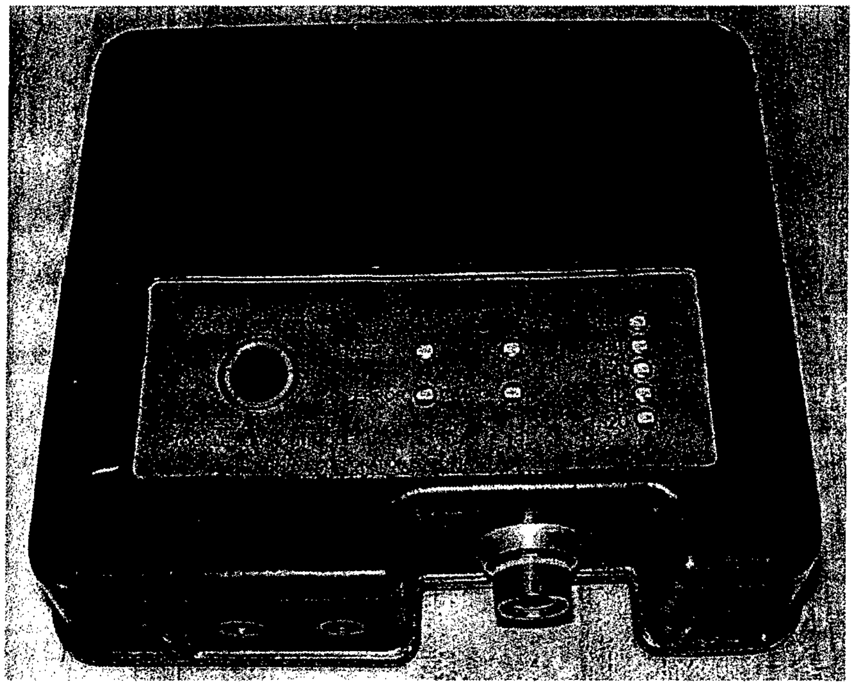


Figure 9. First-pass case design. This two-piece design holds the AC-DC converter's heat-sink against the inside wall of the case. The charger's PCB location utilizes a PCB-mounted bulkhead connector, rather than cable/wires between the PCB and the connector.

The SLA model, while good for checking form and component fit, is not suitable for temperature or other environmental testing. Thus, while the case design and SLA model were being completed, an off-the-shelf enclosure, of approximately the same size and volume as the charger's custom case, was used to perform some temperature testing of the AC-DC converter. Unfortunately, it was discovered that this design was not adequate for the heat dissipation requirements of the AC-DC converter. Instead, it became apparent that an additional heat-sink would be required in order to move heat to the outside of the case.

The second-pass case design included a number of changes in order to accommodate an added heat-sink that protrudes through the wall of the case. While attempting to both minimize the overall size of the case and accommodate the significant height change that the external heat-sink, the layout of the PCB, bulkhead connector, and cable exits was also changed. In addition, the new case design required attachment points and other features to allow mounting of a heat shield – which is mounted over the external heat-sink in order to prevent contact with the hot heat-sink during operation of the charger. Figure 10 shows a completed charger, built with the second-pass case design. Because of the need for the external heat-sink, this final design has an envelope volume of 55 cubic inches – which slightly exceeds the design goal of 50 cubic inches.

Figure 10. The final case design is taller, to allow for additional heat-sinking for the AC-DC converter. The cable and connector arrangement has been changed, with the bulkhead connector now connecting to the PCB through wires.

ASSEMBLY AND TESTING

Fifteen units, ten for delivery to the Army and five for environmental testing and fall-out, were assembled in-house. Overall, the assembly process went smoothly, though a few issues were identified that would need to be addressed before high-volume production could begin. For example, the cable assemblies for these prototype units did not have a molded-on strain relief – this required extra assembly effort, including application of a sealant, that would not be needed if more complete cable assemblies were used. Another issue was sealing of the external heat-sink to the case – which was, for the prototypes, done with manually applied sealant. For high-volume production the heat-sink would be modified to include an o-ring groove, or other means of sealing to the case. Despite these minor assembly issues, the assembled prototypes performed as expected. To help illustrate the assembly of the units, Fig. 11 shows an exploded view of the charger.

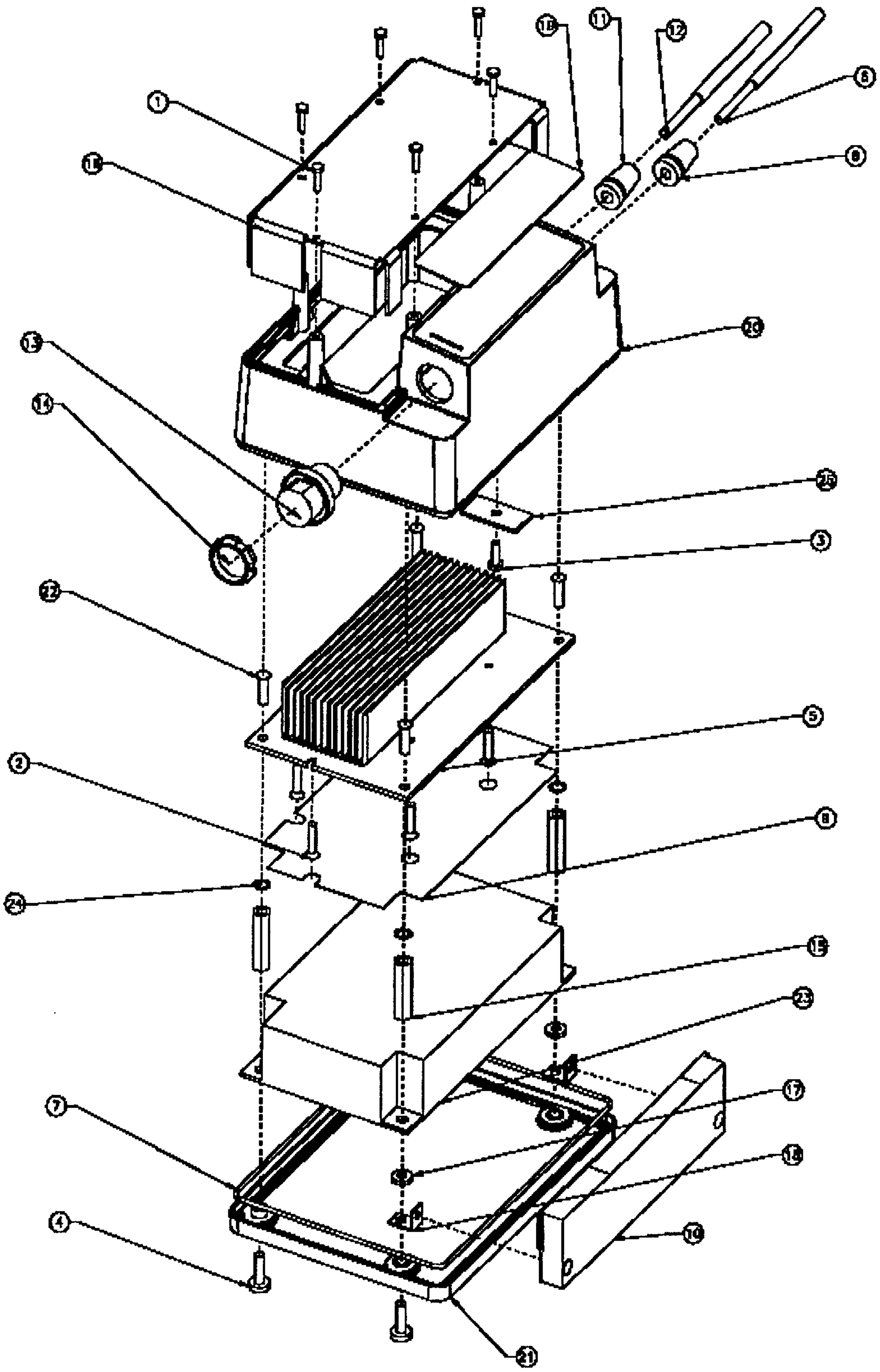


Figure 11. Exploded-view drawing of the final case design and charger assembly.

Upon completion of the assembly of the prototype units, all units were tested for basic functionality. Then, three units were sent to an outside testing facility for completion of the required environmental tests. While the environmental testing was being completed, the remaining units were further tested – with each unit undergoing a complete charge cycle and a daisy-chain test. Figure 12 illustrates a 3-unit daisy-chain configuration. Using all of the prototype units, a full ten-unit chain was also tested in order to verify the functionality of the units in the maximum configuration. A test was also done with more than ten units – showing that an units beyond the tenth unit remain inactive.

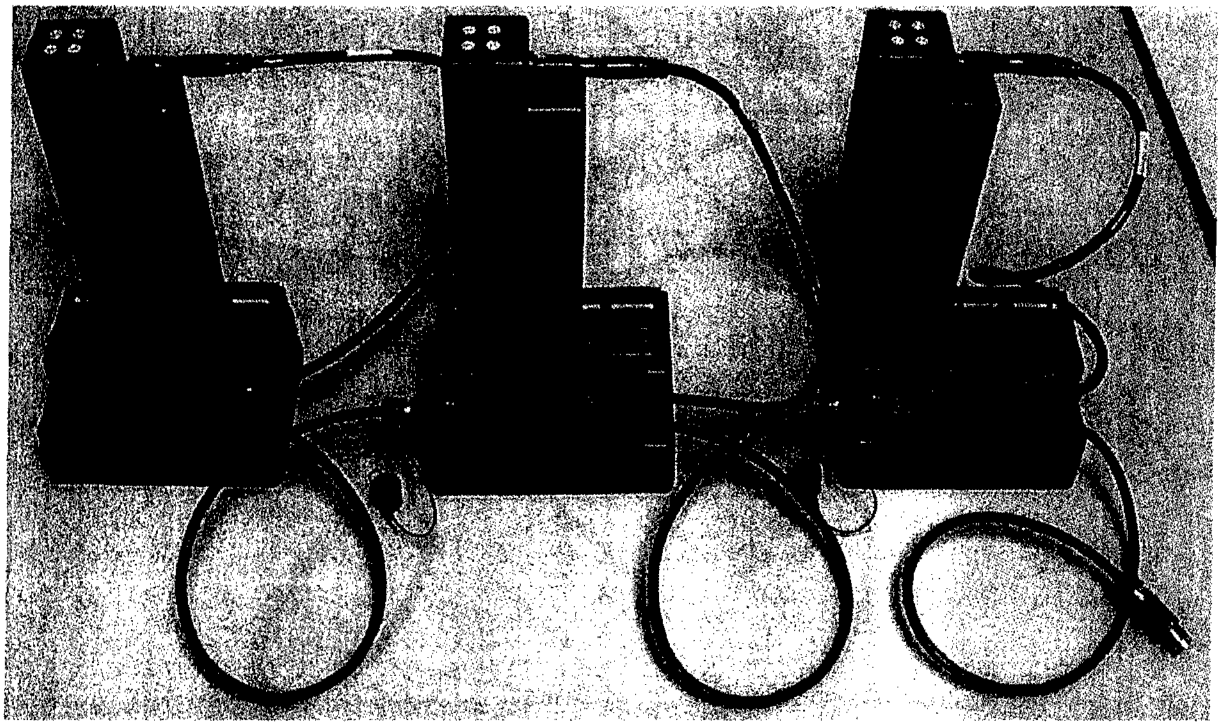


Figure 12. Three chargers ganged together to illustrate the daisy-chain capability of the charger design. The charger on the right is the master, and would connect to the power source. The other two chargers have their input cables connected to the bulkhead connector of the charger to their right.

For these initial prototypes, the firmware was designed to evenly distribute the equivalent of a single-unit's output, i.e. 5 A maximum charge current, among all ganged units. It should be noted, however, that the charge distribution algorithm/behavior is entirely under firmware control – and the firmware is field upgradeable. While the capacity of the wire in the input cables restricts the total power that can be drawn by a ganged system, the power distribution algorithm could readily be changed to increase the total system power without exceeding the input cable's rating. With an AC input – which can be detected by the charger circuitry – the system should be capable of maintaining full output power on at least six units, probably eight units, and possibly all ten units, simultaneously. Similarly, maximum output power could probably be maintained on three units simultaneously when operating from a DC input. In choosing the conservative power distribution algorithm that was used in these initial prototype units, wire tables were used to determine safe current levels. These standard tables usually include a bundle-current rating, a rating of the maximum allowed current, for a given temperature rise, for a wire that is in a bundle/cable. These tables also assume that all of the wires in the bundle are carrying the same current. For the charger, not all of the wires are carrying the current, and the number of wires in the bundle is relatively small. Both of these factors should allow the wire the carry a higher current. Empirical testing would help to determine a suitable maximum.

Test reports for the environmental tests for altitude, humidity, thermal shock, vibration, and loose cargo are given in Appendices A through E, respectively. A single-unit drop test was done internally at NVE. For this test, a room temperature charger was suspended by its input and output cables, at a height of 32 inches above bare concrete, and then released. The charger remained intact, with a minor deformation/dent of the case on the corner that first contacted the floor. The charger was still functional following this drop test.

APPENDIX A – ALTITUDE TEST

environ LABORATORIES LLC

9725 GIRARD AVENUE SOUTH
MINNEAPOLIS, MINNESOTA 55431-2621

ENGINEERING REPORT NO. 31645-1

ALTITUDE TEST

for

NVE, INC.
11409 VALLEY VIEW ROAD
MINNEAPOLIS, MN 55344

PREPARED BY:	Phillip M. Toftely Test Engineer
	Daniel J. Larson Senior Test Technician
	David M. Gillen Vice President
APPROVED BY:	Charles W. Mapes Project Engineer

REVISION HISTORY

Revision	Total Number of Pages	Date	Description
--	8	27 June 2005	Original

PREPARED FOR:	TEST DATES:	
NVE, INC. 11409 VALLEY VIEW ROAD MINNEAPOLIS, MN 55344 ATTN: Mr. Tom Norkunas	Start:	6/15/2005
	Completion:	6/15/2005
	ENVIRON TEST NO.:	31645-1
	PURCHASE ORDER NO.:	07741
	PURCHASE DATE:	6/9/2005

ALTITUDE TEST

1.0 ABSTRACT

1.1 Object

Subject the X1EC001-13 Smart Charger, S/N 000003, to an Altitude Test in accordance with Smart Charger Phase II Requirements, Paragraph 2.1.

1.2 Conclusions

Visual examination revealed no evidence of visual and mechanical defects, as defined in Table B of Smart Charger Phase II Requirements. The test unit was retained at Environ Laboratories LLC for further testing.

2.0 UNIT(S) TESTED

MANUFACTURER:	NVE, INC.
DEVICE:	Smart Charger
MODEL/PART NO.:	X1EC001-13
SERIAL NO.:	000003

The results of this test apply only to the units identified in this Engineering Report by device identifier and model / part number, or serial number.

3.0 TEST REQUESTED

Subject the Smart Charger to the following test profile:

1. Place the Smart Charger and connectors in an altitude chamber.
2. Establish and maintain an altitude of 50,000 feet and a chamber temperature of 75 ±5°F. Hold these conditions for 6 hours.
3. Remove the test articles from the altitude chamber at the completion of the 6-hour exposure. Examine the test articles for visual and mechanical defects as defined in Table B of Smart Charger Phase II Requirements.

4.0 INSTRUMENTATION, PROCEDURE AND RESULTS

4.1 Instrumentation

All instrumentation is calibrated regularly by instruments directly traceable to the National Institute of Standards and Technology, and in accordance with MIL-I-45208A, ANSI/NCSL Z540-1-1994 and ISO/IEC 17025:1999.

Equipment Number	Description	Manufacturer	Model Number	Last Calibration	Due Calibration	Range
200-076	Temperature Controller Recorder	Honeywell	AR52ACD0051	1/17/2005	7/17/2005	0 to +200°F
710-202	Digital Pressure Gauge	Meriam Instruments	2110-AI2000	4/22/2005	4/22/2006	0 to 2000mmHg

4.2 Procedure

The Smart Charger and connectors were placed in a pressure vessel. The air pressure was reduced to the equivalent of 50,000 feet altitude (87 mm Hg). Temperature was held at 75 ±5°F. These conditions were maintained for 6 hours. At the completion of the exposure period, the test articles were removed from the pressure vessel and examined for visual and mechanical defects.

4.3 Results

Visual examination revealed no evidence of visual and mechanical defects, as defined in Table B of Smart Charger Phase II Requirements. The test data sheet, chamber temperature chart and photograph are included herein. The test unit was retained at Environ Laboratories LLC for further testing.

environ Laboratories LLC
9725 Girard Avenue South
Minneapolis MN 55431

Page 1 of 1
Date 6/15/05
Job Number 31645-1

DATA SHEET

COMPANY: NVE, Inc.	
DEVICE: Battery Charger, Smart, Level 3	
MODEL NO. X1EC001-13	S/N: 000003
TEST: Altitude	SPEC: Final Version - Smart Charger Phase II PARA: 2.1

50,000 feet = 87.3 mm Hg
Started reducing pressure at 10:10 AM
Reached 50,000 feet at 10:35 AM
Maintained 50,000 feet until 4:40 PM
Returned to ambient pressure over 30 minutes

No visible damage

710-202, 200-076

Test Performed By:

QAF 5.3.1 Rev A ISSUED BY: MICHAEL S. WOOD 5/26/2000

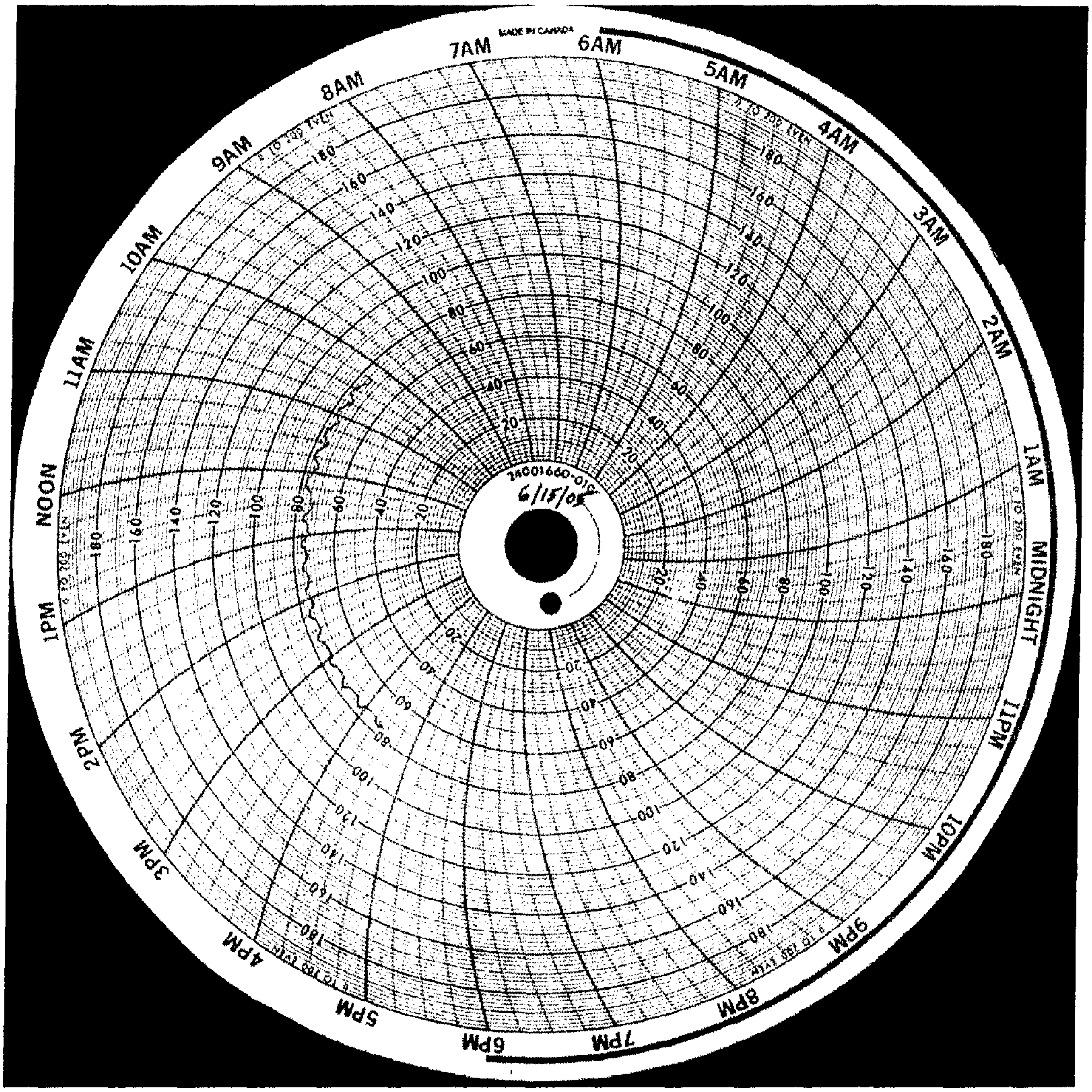
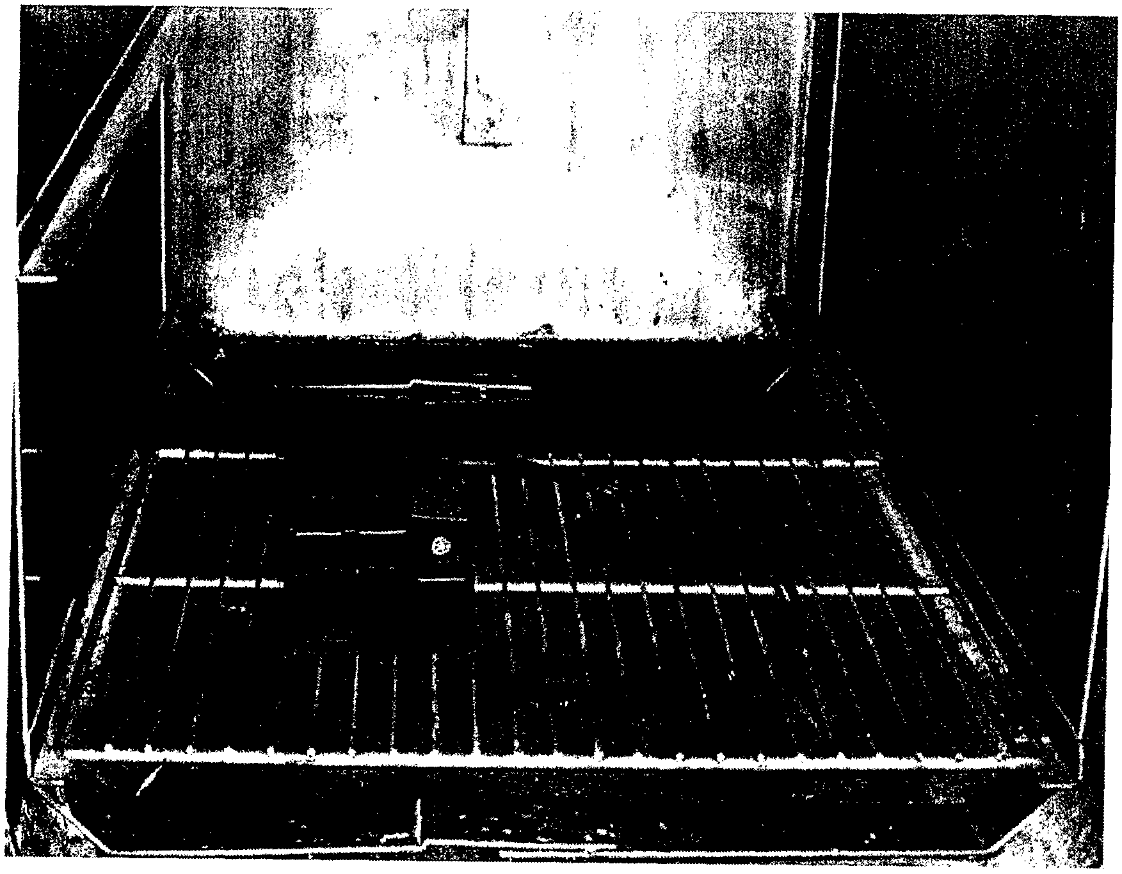


Chart No. 1: Chamber temperature in °F.



Photograph No. 1: Smart Charger placed in the pressure vessel.

APPENDIX B – HUMIDITY TEST

environ®
LABORATORIES LLC

9725 GIRARD AVENUE SOUTH
MINNEAPOLIS, MINNESOTA 55431-2621

ENGINEERING REPORT NO. 31645-2

HUMIDITY TEST

for

NVE, INC.
11409 VALLEY VIEW ROAD
MINNEAPOLIS, MN 55344

PREPARED BY:	Phillip M. Toftely Test Engineer
APPROVED BY:	David M. Gillen Vice President

REVISION HISTORY

Revision	Total Number of Pages	Date	Description
--	9	11 July 2005	Original

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	ENVIRON TEST NO.:	31645-2
ATTN: Mr. Tom Norkunas	PURCHASE ORDER NO.:	07741
	PURCHASE DATE:	6/9/2005

HUMIDITY TEST

1.0 ABSTRACT

1.1 Object

Subject the X1EC001-13 Smart Charger, S/N 000004, to a Humidity Test in accordance with Smart Charger Phase II Requirements, dated 8/12/2004, Paragraph 2.2.

1.2 Conclusions

Visual examination of the test unit revealed no evidence of mechanical defects as defined in Table B of Smart Charger Phase II Requirements, dated 8/12/2004. The test unit was returned to NVE, Inc. upon completion of the test.

2.0 UNIT(S) TESTED

MANUFACTURER:	NVE, INC.
DEVICE:	Smart Charger
MODEL/PART NO.:	X1EC001-13
SERIAL NO.:	000004

The results of this test apply only to the units identified in this Engineering Report by device identifier and model / part number, or serial number.

3.0 TEST REQUESTED

Subject the Smart Charger to the following test profile:

1. Place the Smart Charger and connectors in the environmental test chamber.
2. Raise the chamber temperature to 130 ±4°F over a period of 2 hours. Control the relative humidity to not less than 95%. Maintain these test conditions for 6 hours.
3. Reduce the chamber temperature to 86 ±4°F in 16 hours while maintaining a relative humidity of not less than 85%.
4. Repeat this 24-hour cycle for a total of 10 cycles (240 hours) of exposure time.
5. Upon completion of the humidity test, visually examine the Smart Charger and connectors for evidence of visual and mechanical defects as defined in Table B of Smart Charger Phase II Requirements, dated 8/12/2004.

4.0 INSTRUMENTATION, PROCEDURE AND RESULTS

4.1 Instrumentation

All instrumentation is calibrated regularly by instruments directly traceable to the National Institute of Standards and Technology, and in accordance with MIL-I-45208A, ANSI/NCSL Z540-1-1994 and ISO/IEC 17025:1999.

Equipment Number	Description	Manufacturer	Model Number	Last Calibration	Due Calibration	Range
200-201	Temperature Chart Recorder	Honeywell	Truline DR45AT	12/22/2004	6/22/2005	-80 to +350°F; 0 to 100% R/H
200-202	Temperature Controller	JC Systems Inc	620A	7/16/2003	7/16/2005	-418 to +599°F
500-056	Temperature / Humidity Chamber	Thermotron	FM35-CHM-5-5-810C	N/A	N/A	-100 to +350°F; 20 to 98% R/H

4.2 Procedure

The Smart Charger and connectors were placed in the environmental test chamber and the chamber was sealed. The chamber controller was programmed to follow the test profile described in Section 3.0 of this report. The 24-hour cycle was initiated and the temperature/humidity exposure was continued for 10 days (240 hours) of exposure time. At the completion of the exposure, the Smart Charger and connectors were removed from the chamber and examined for visual and mechanical defects.

4.3 Results

Visual examination of the test unit revealed no evidence of mechanical defects as defined in Table B of Smart Charger Phase II Requirements, dated 8/12/2004. The test data sheet, representative chamber chart recording and setup photograph are included in this report. The test unit was returned to NVE, Inc. upon completion of the test.

environ Laboratories LLC
9725 Girard Avenue South
Minneapolis MN 55431

Page 1 of 1
Date 6/17/05
Job Number 31645-2

DATA SHEET

[redacted]

2 hours ramp to 130°F and 95% RH
6 hours hold 130°F and 95% RH
16 hours ramp to 86°F and 95% RH
10 cycles

Started test at 9:55 AM on 6/17/05
Stopped test at 10:00 AM on 6/27/05

No visible damage

500-056, 200-202, 200-201

Test Performed By: [signature]

QAF 5.3.1 Rev A   ISSUED BY: MICHAEL S. WOOD   5/26/2000

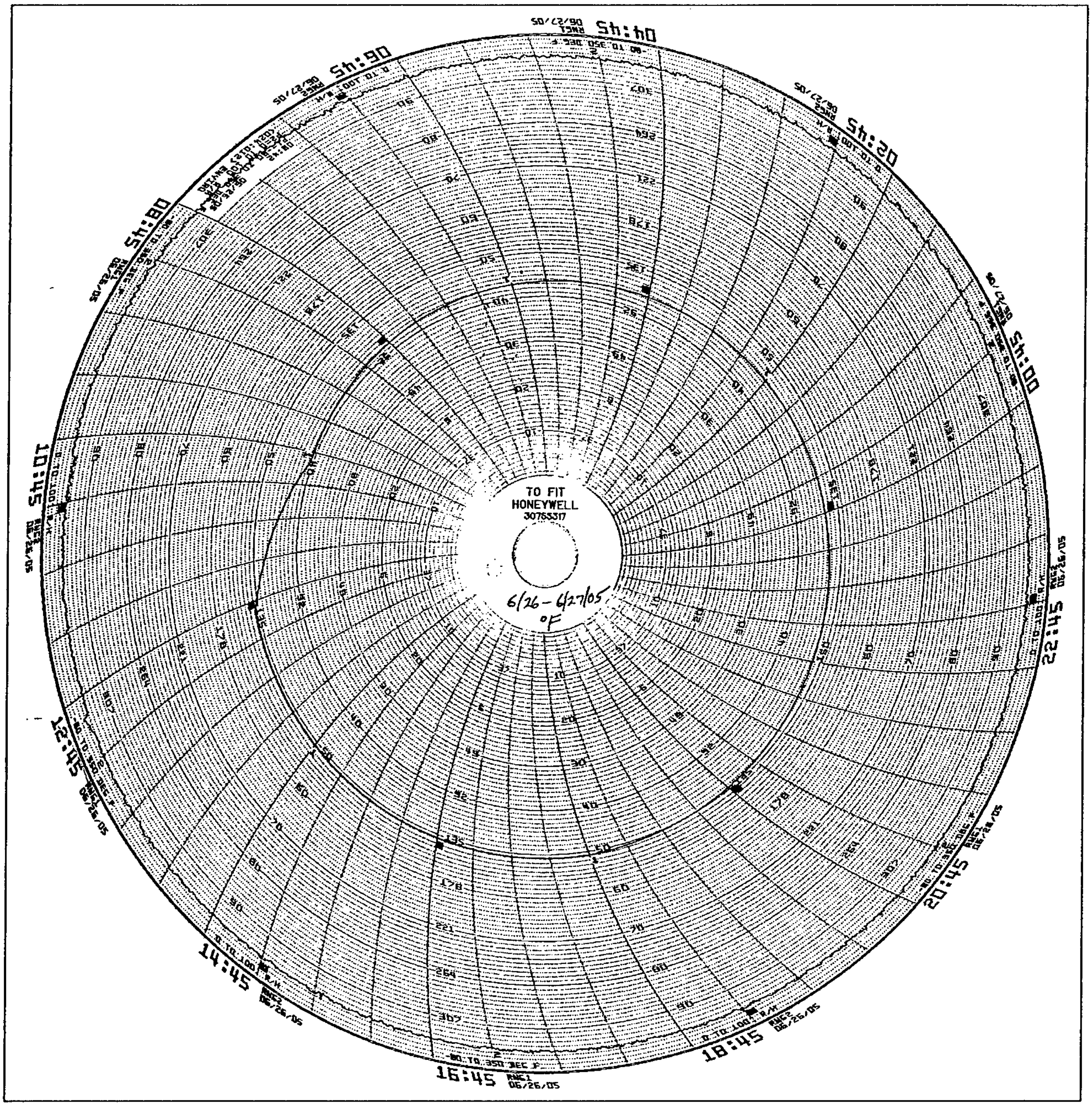
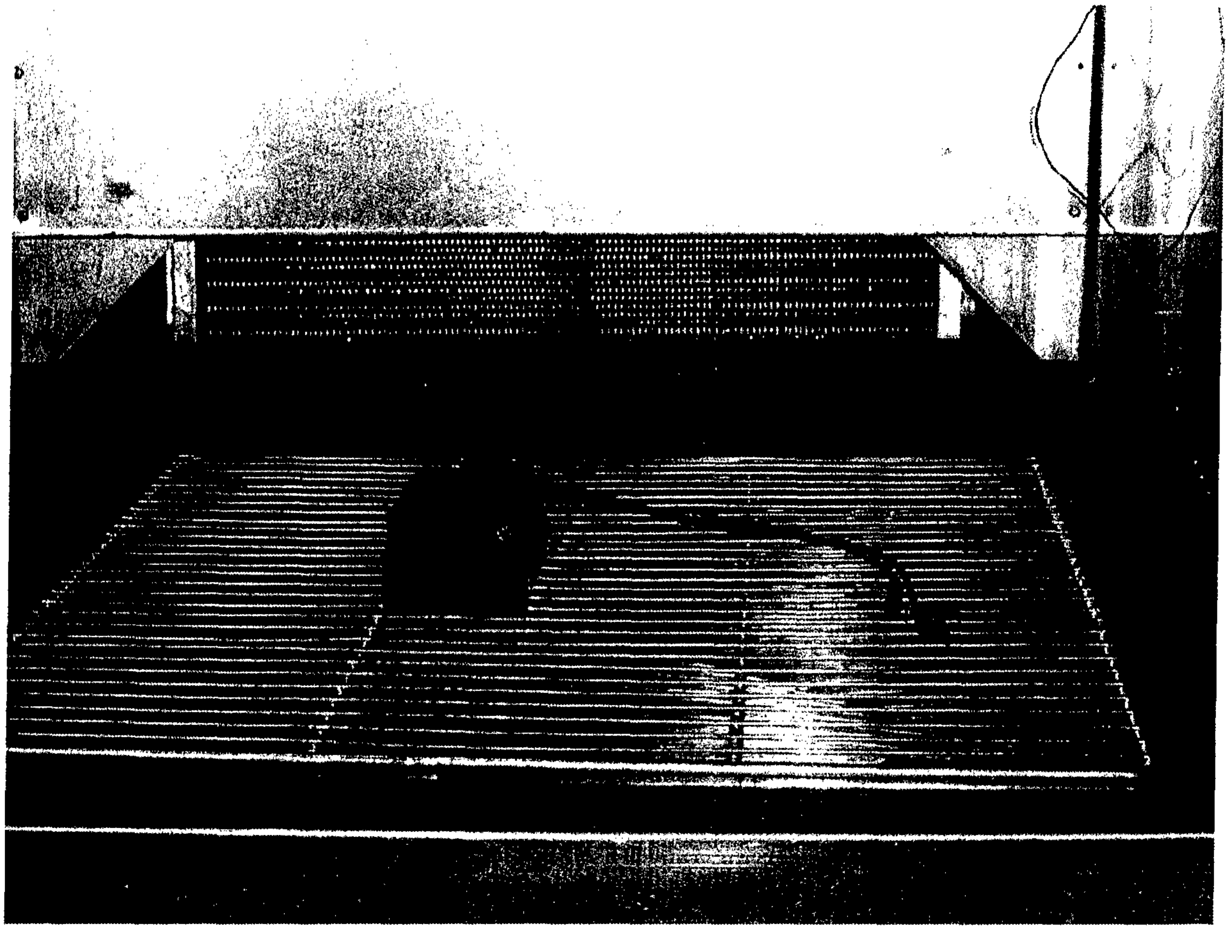


Chart No. 1: Representative temperature/humidity chart, scaled for –80 to +350°F, and 0 to 100% R/H



Photograph No. 1: Smart Charger placed in temperature/humidity chamber.

APPENDIX C – THERMAL SHOCK TEST

environ LABORATORIES LLC

9725 GIRARD AVENUE SOUTH
MINNEAPOLIS, MINNESOTA 55431-2621

ENGINEERING REPORT NO. 31645-3

THERMAL SHOCK TEST

for

NVE, INC.
11409 VALLEY VIEW ROAD
MINNEAPOLIS, MN 55344

PREPARED BY:	Phillip M. Toftely Test Engineer
APPROVED BY:	David M. Gillen Vice President

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	PURCHASE ORDER NO.:	07741
ATTN: Mr. Tom Norkunas	PURCHASE DATE:	6/9/2005

THERMAL SHOCK TEST

1.0 ABSTRACT

1.1 Object

Subject the X1EC001-13 Smart Charger, S/N 000003, to a Thermal Shock Test in accordance with Smart Charger Phase II Requirements, Paragraph 2.3. Temperature extremes shall be –20 ±5°F and 130 ±5°F.

1.2 Conclusions

The Smart Charger and connectors were visually inspected at the end of the test for visual and mechanical defects as identified in Table B of Smart Charger Phase II Requirements. No defects were found.

2.0 UNIT(S) TESTED

MANUFACTURER:	NVE, INC.
DEVICE:	Smart Charger
MODEL/PART NO.:	X1EC001-13
SERIAL NO.:	000003

The results of this test apply only to the units identified in this Engineering Report by device identifier and model / part number, or serial number.

3.0 TEST REQUESTED

Place the Smart Charger and connectors into the environmental chamber. Stabilize the test articles at –20 ±5°F and hold for a minimum of 4 hours. Transfer the test articles to a chamber set for 130 ±5°F within 5 minutes. During the transfers, the test articles shall be exposed to the normal inspection condition of room ambient temperature. Hold the test articles at the elevated temperature for a minimum of 4 hours. The minimum 4-hour temperature soaks shall be counted from the time the chamber restabilizes at the set temperature. Continue this procedure until a total of five 8-hour cycles of low-temperature and high-temperature exposure have been completed. At the completion of the test, store the test articles at room ambient temperature for a minimum of 4 hours. Visually inspect the test articles for visual and mechanical defects as identified in Table B of Smart Charger Phase II Requirements.

4.0 INSTRUMENTATION, PROCEDURE AND RESULTS

4.1 Instrumentation

All instrumentation is calibrated regularly by instruments directly traceable to the National Institute of Standards and Technology, and in accordance with MIL-I-45208A, ANSI/NCSL Z540-1-1994 and ISO/IEC 17025:1999.

Equipment Number	Description	Manufacturer	Model Number	Last Calibration	Due Calibration	Range
200-113	Temperature Chart Recorder	Partlow	MRC 7000	12/22/2004	6/22/2005	-150 to +350°F
200-214	Temperature Controller	Watlow	F4	7/17/2003	7/18/2005	-200 to +800°C
500-061	Thermal Shock Chamber	Cincinnati Sub-Zero	VTS-3.3	N/A	N/A	-103 to +410°F

4.2 Procedure

The Smart Charger and connectors were placed in the cold section of the thermal shock chamber, stabilized at –20 ±5°F, and held for a minimum of 4 hours. The test articles were then manually transferred to the hot section of the chamber, stabilized at 130 ±5°F, and held for a minimum of 4 hours. This procedure was continued until five 8-hour cycles of low-temperature and high-temperature exposure had been completed. The test articles were then stored at room ambient conditions for a minimum of 4 hours. A visual inspection of the test articles was then conducted.

4.3 Results

The Smart Charger and connectors were visually inspected at the end of the test for visual and mechanical defects as identified in Table B of Smart Charger Phase II Requirements. No defects were found. The test data sheet, chamber temperature charts and setup photograph are included in this report. The test unit remained at Environ Laboratories LLC for further testing.

Date 6/16/05
Job Number 31645-3

environ Laboratories LLC
9725 Girard Avenue South
Minneapolis MN 55431

DATA SHEET

COMPANY: NVE, Inc.	
DEVICE: Battery Charger, Smart, Level 3	
MODEL NO. X1EC001-13	S/N: 000003
TEST: Thermal Shock	SPEC: Final Version Smart Charger Phase II PARA: 2.3

-20°F = -29°C
+130°F = +55°C

Placed unit in chamber and reduced temperature to -29°C
Remained at -29°C for 4 hours
Removed from cold chamber and placed unit in hot (+55°c) chamber
Removed from hot chamber and moved to cold chamber
6/17/05
Removed from cold chamber and moved to hot chamber
Removed from hot chamber and moved to cold chamber
Removed from cold chamber and placed in hot chamber
Removed from Hot chamber and placed in cold chamber
6/18/05
Removed from cold chamber and placed in hot chamber
Removed from hot chamber and placed in cold chamber
Removed from cold chamber and placed in hot chamber
Removed from hot chamber and stabilized at ambient
No visible damage
500-061, 200-214, 200-113

Test Performed By: [signature]

QAF 5.3.1 Rev A ISSUED BY: MICHAEL S. WOOD 5/26/2000

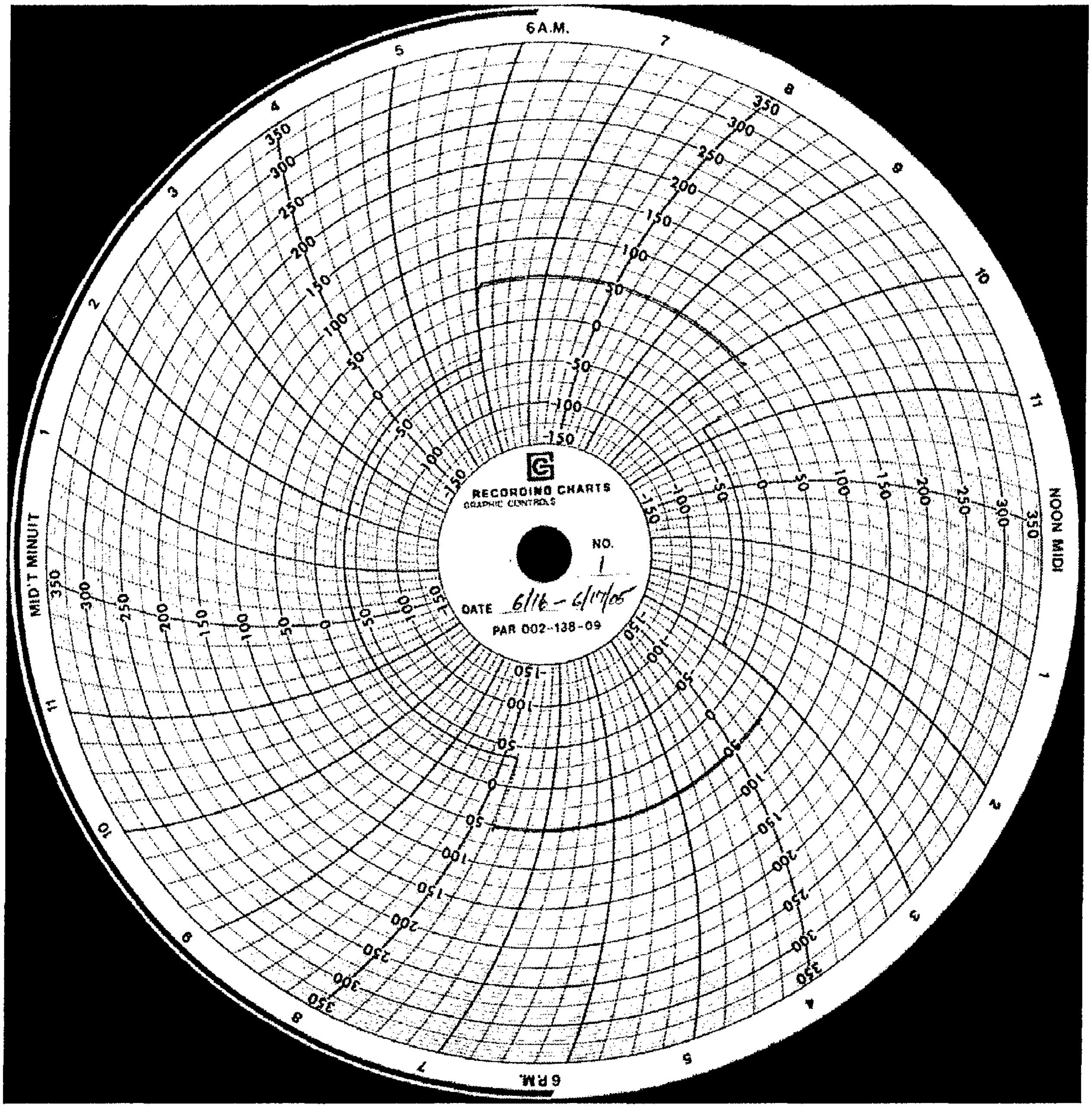


Chart No. 1: Chamber temperature in °C.

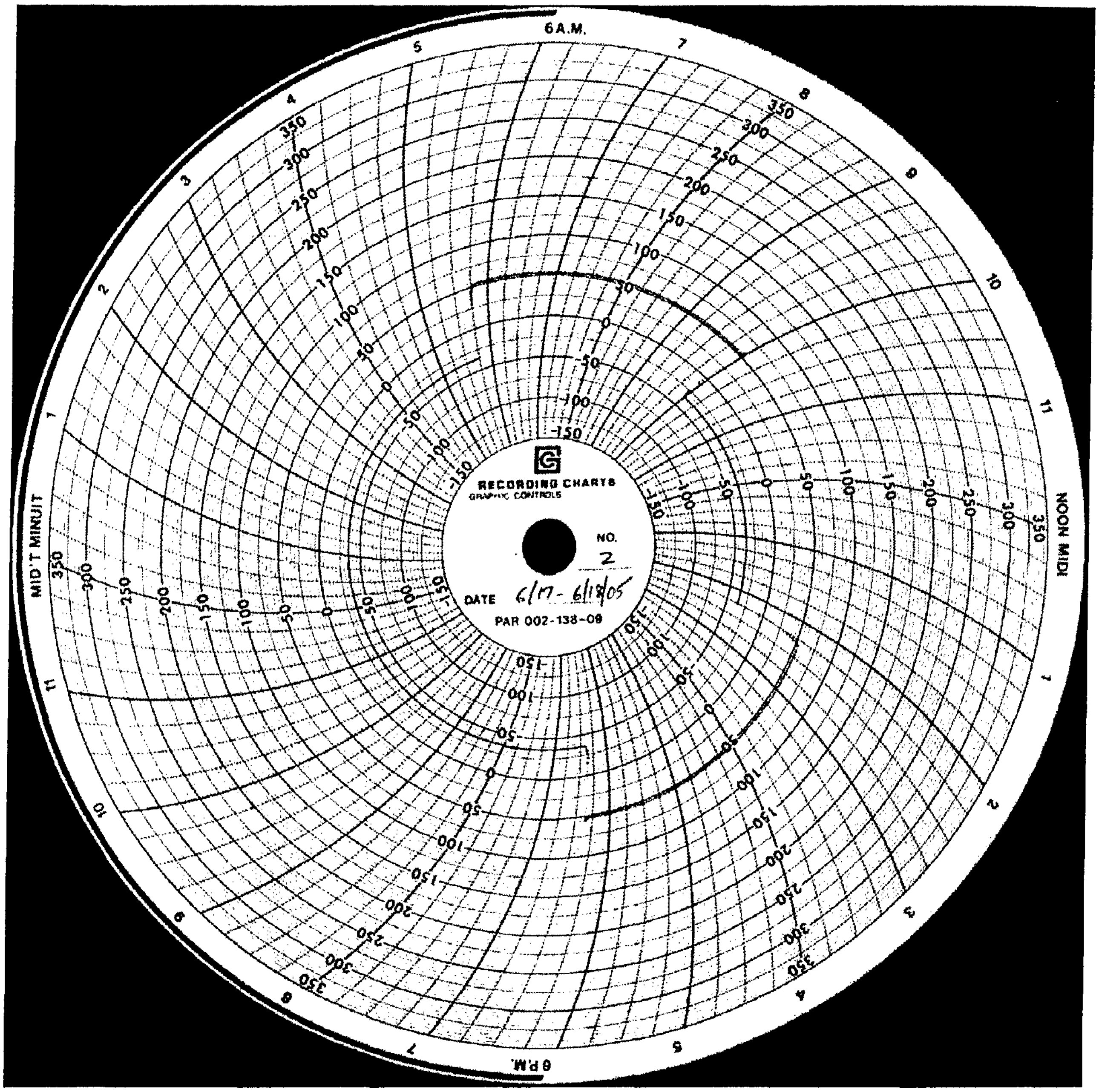


Chart No. 2: Chamber temperature in °C.

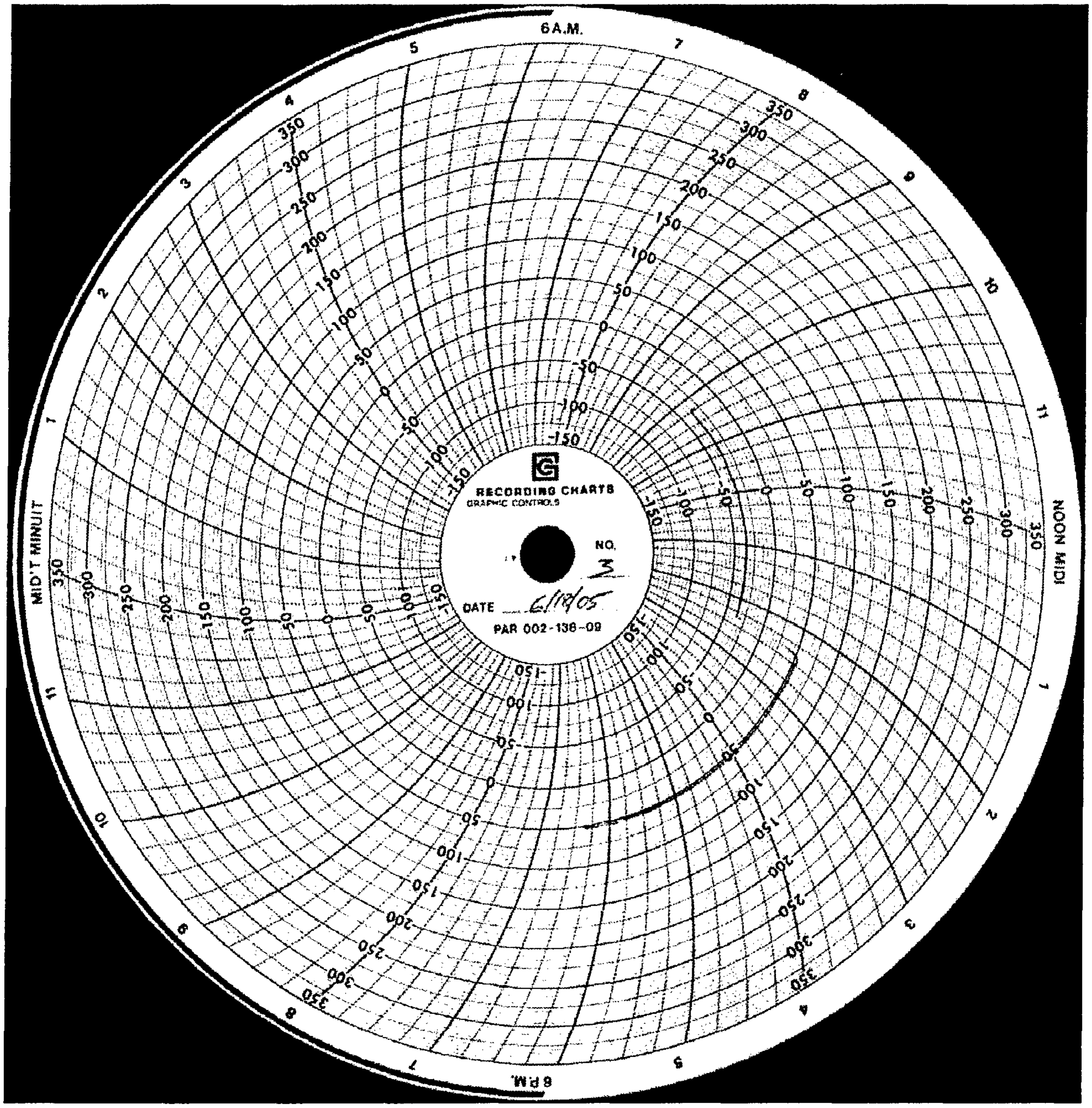
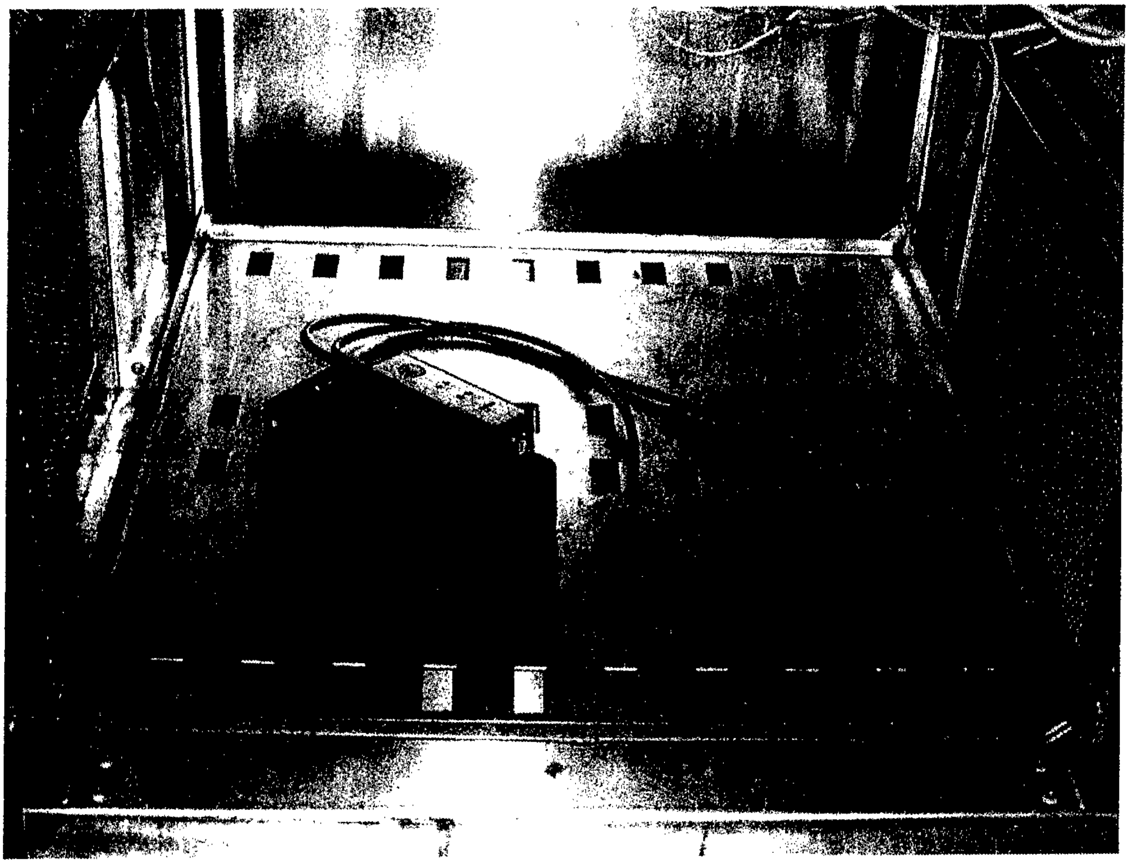


Chart No. 3: Chamber temperature in °C.



Photograph No. 1: Smart Charger placed in thermal shock chamber.

APPENDIX D – VIBRATION TEST

environ LABORATORIES LLC

9725 GIRARD AVENUE SOUTH
MINNEAPOLIS, MINNESOTA 55431-2621

ENGINEERING REPORT NO. 31645-4

VIBRATION TEST

for

NVE, INC.
11409 VALLEY VIEW ROAD
MINNEAPOLIS, MN 55344

PREPARED BY:	Michael J. Caron Test Engineer
	Kent L. Erickson Dynamics Division Manager
APPROVED BY:	Charles W. Mapes Project Engineer

REVISION HISTORY

Revision	Total Number of Pages	Date	Description
--	10	22 July 2005	Original

PREPARED FOR:	TEST DATES:	
NVE, INC. 11409 VALLEY VIEW ROAD MINNEAPOLIS, MN 55344	Start:	7/7/2005
	Completion:	7/8/2005
	ENVIRON TEST NO.:	**31645-4**
ATTN: Mr. Tom Norkunas	**PURCHASE ORDER NO.:**	**07741**
	PURCHASE DATE:	6/9/2005

VIBRATION TEST

1.0 ABSTRACT

1.1 Object

Subject one (1) Battery Charger to a Vibration Test as requested in NVE, Inc. Purchase Order No. 07741, dated June 9, 2005.

1.2 Conclusions

Upon completion of the Vibration Test, the test unit remained intact and appeared to have incurred no visible evidence of damage or degradation as a result of the test.

2.0 UNIT(S) TESTED

MANUFACTURER:	NVE, INC.
DEVICE:	One (1) Battery Charger
MODEL/PART NO.:	XIEC001-13
SERIAL NO.:	000002

The results of this test apply only to the units identified in this Engineering Report by device identifier and model / part number, or serial number.

3.0 TEST REQUESTED

Subject the test unit to the Vibration Test outlined in Smart Charger Phase II Requirements, Final Version, dated 8/12/2004, as follows:

Frequency (Hz)	Excitation
10 – 55	0.06" D.A.
Sweep Rate:	1 Hz/minute (linear)
Duration:	1 hour 30 minutes 21 seconds in each of three mutually perpendicular axes.

4.0 INSTRUMENTATION, PROCEDURE AND RESULTS

4.1 Instrumentation

All instrumentation is calibrated regularly by instruments directly traceable to the National Institute of Standards and Technology, and in accordance with MIL-I-45208A, ANSI/NCSL Z540-1-1994 and ISO/IEC 17025: 1999.

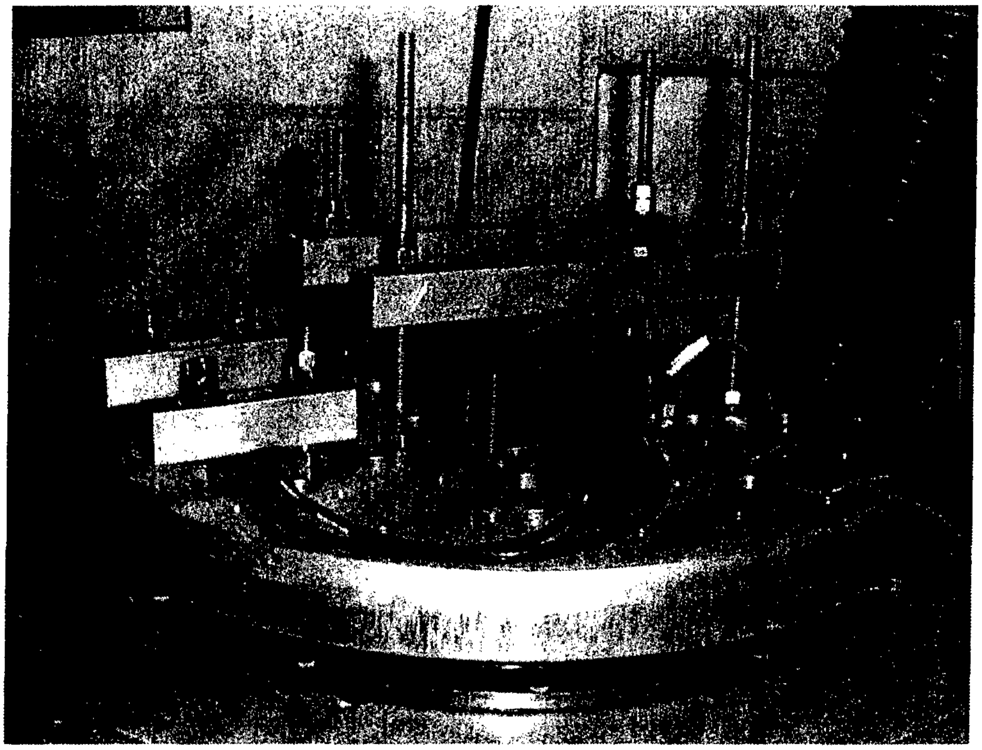
Equipment Number	Description	Manufacturer	Model Number	Last Calibration	Due Calibration	Range
204-525	Charge Amplifier	Unholtz-Dickie	122P	3/1/2005	3/1/2006	1 to 100 pC/g, 2Hz to 30kHz
480-112	Accelerometer	Endevco	2226C	3/16/2005	3/16/2006	0 to 1000 g; 5 to 3000 Hz
503-145	Vibration Exciter	Unholtz-Dickie	560	N/A	N/A	5 to 2000 Hz; 6000 F lbs
503-146	Vibration Amplifier	Unholtz-Dickie	MA117A-560	N/A	N/A	5 to 2000 Hz
503-194	Vibration Control System	GenRad	2552B	2/10/2005	8/10/2005	N/A

4.2 Procedure

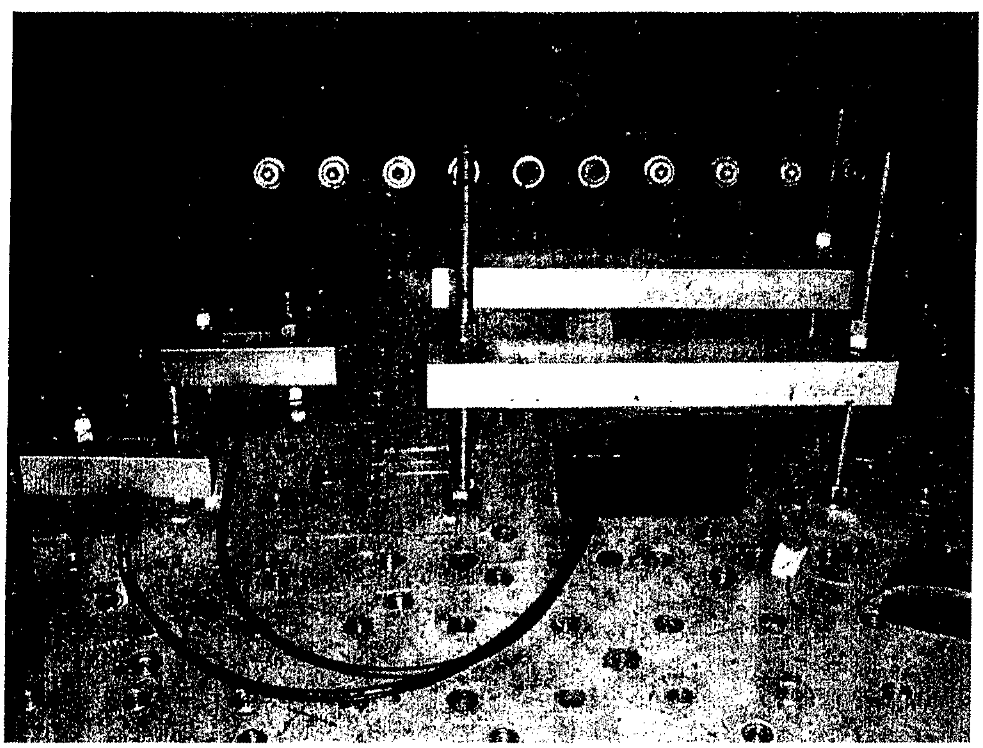
The test unit was secured to a fixture plate, which was coupled to the vertically oriented exciter. A control accelerometer was cemented to the fixture plate, and testing was conducted in the vertical axis. The test setup was next secured to the horizontally oriented slip plate, then finally rotated 90° on the slip plate, and testing was conducted in the longitudinal and latitudinal axes, respectively.

4.3 Results

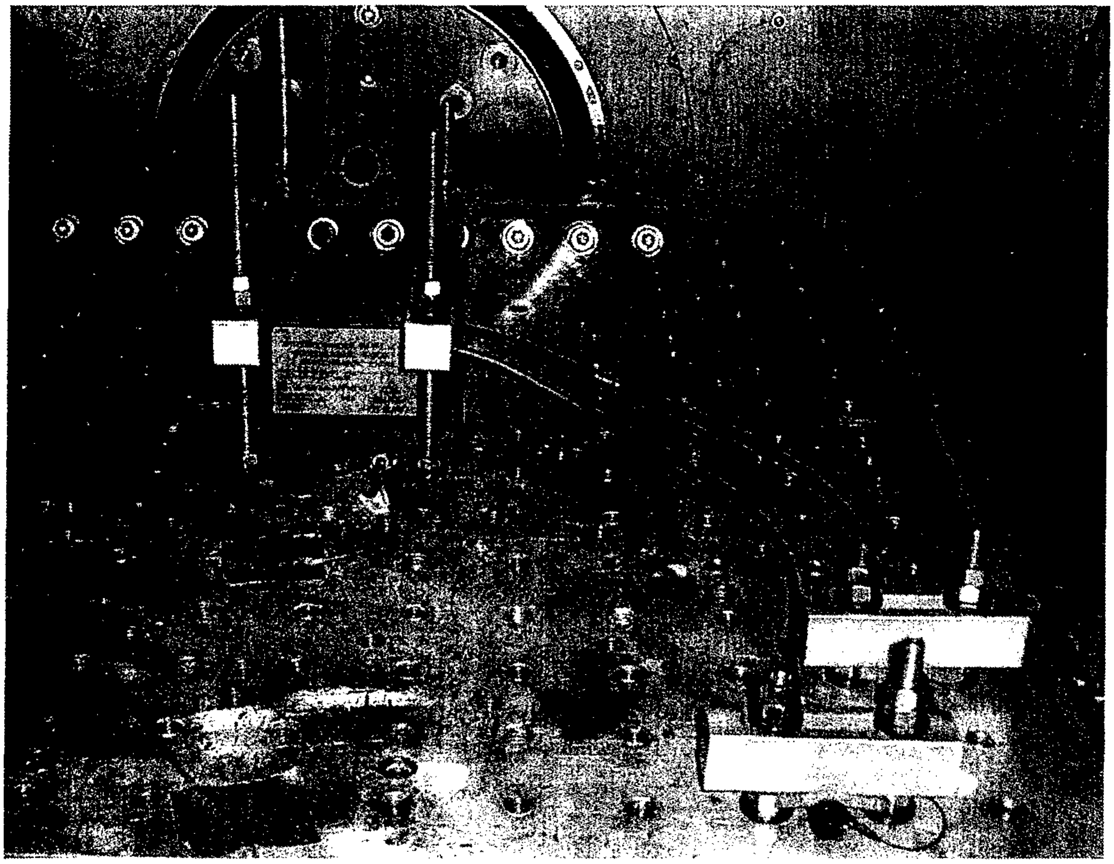
Upon completion of the Vibration Test, the test unit remained intact and appeared to have incurred no visible evidence of damage or degradation as a result of the test.



Photograph No. 1: Test setup secured to the fixture plate and ready for testing in the vertical axis. The control accelerometer is visible cemented to the fixture plate. Applied motion is up-and-down as you view this photograph.



Photograph No. 2: Test setup secured to the slip plate and ready for testing in the longitudinal axis. The control accelerometer is visible cemented to the slip plate. Applied motion is front-to-back as you view this photograph.

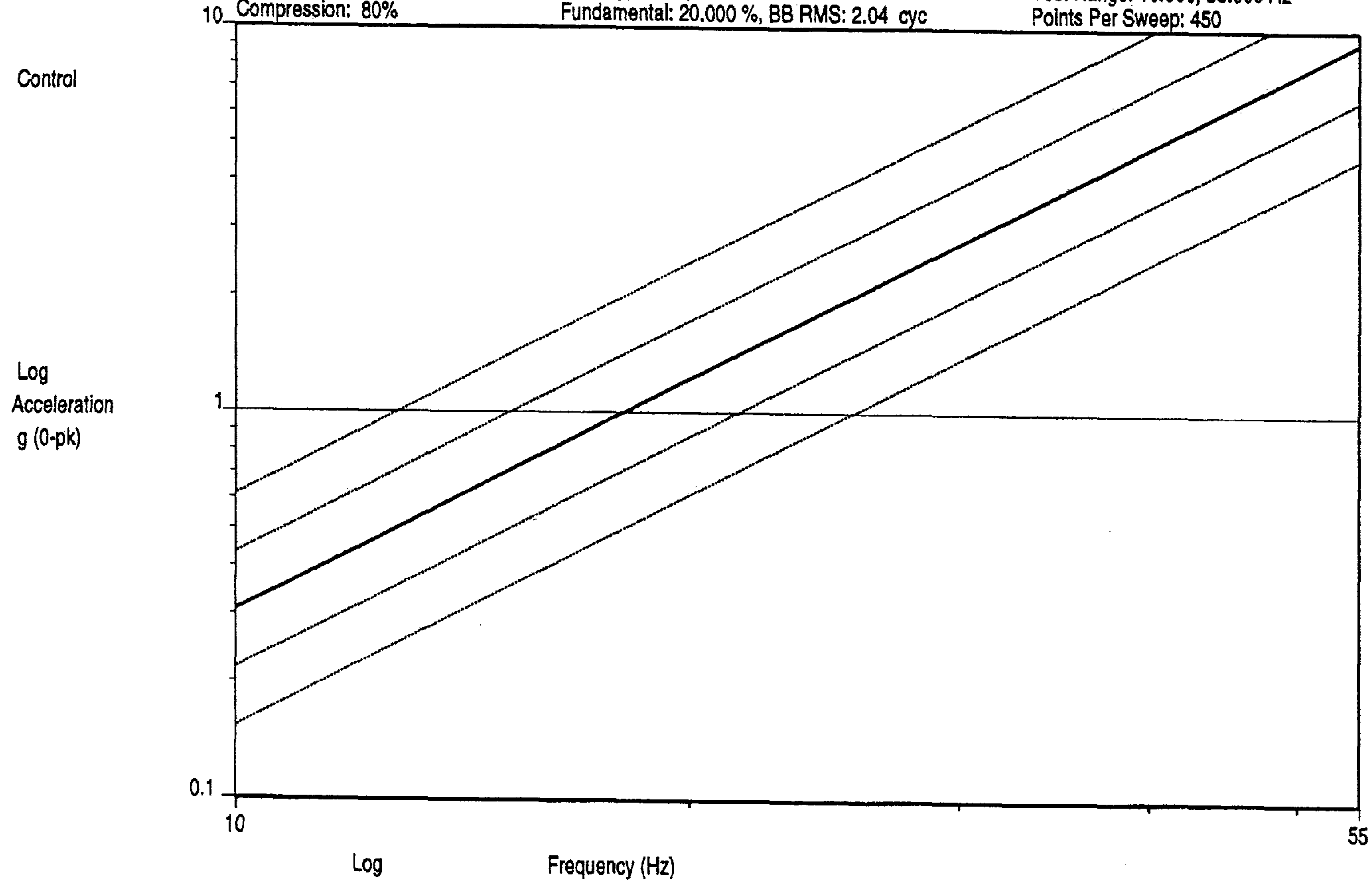


Photograph No. 3: Test setup secured to the slip plate and ready for testing in the latitudinal axis. The control accelerometer is visible cemented to the slip plate. Applied motion is front-to-back as you view this photograph.

Sweep Number: 2.00
Sweep Rate 1: 0.017 Hz/sec
Compression: 80%

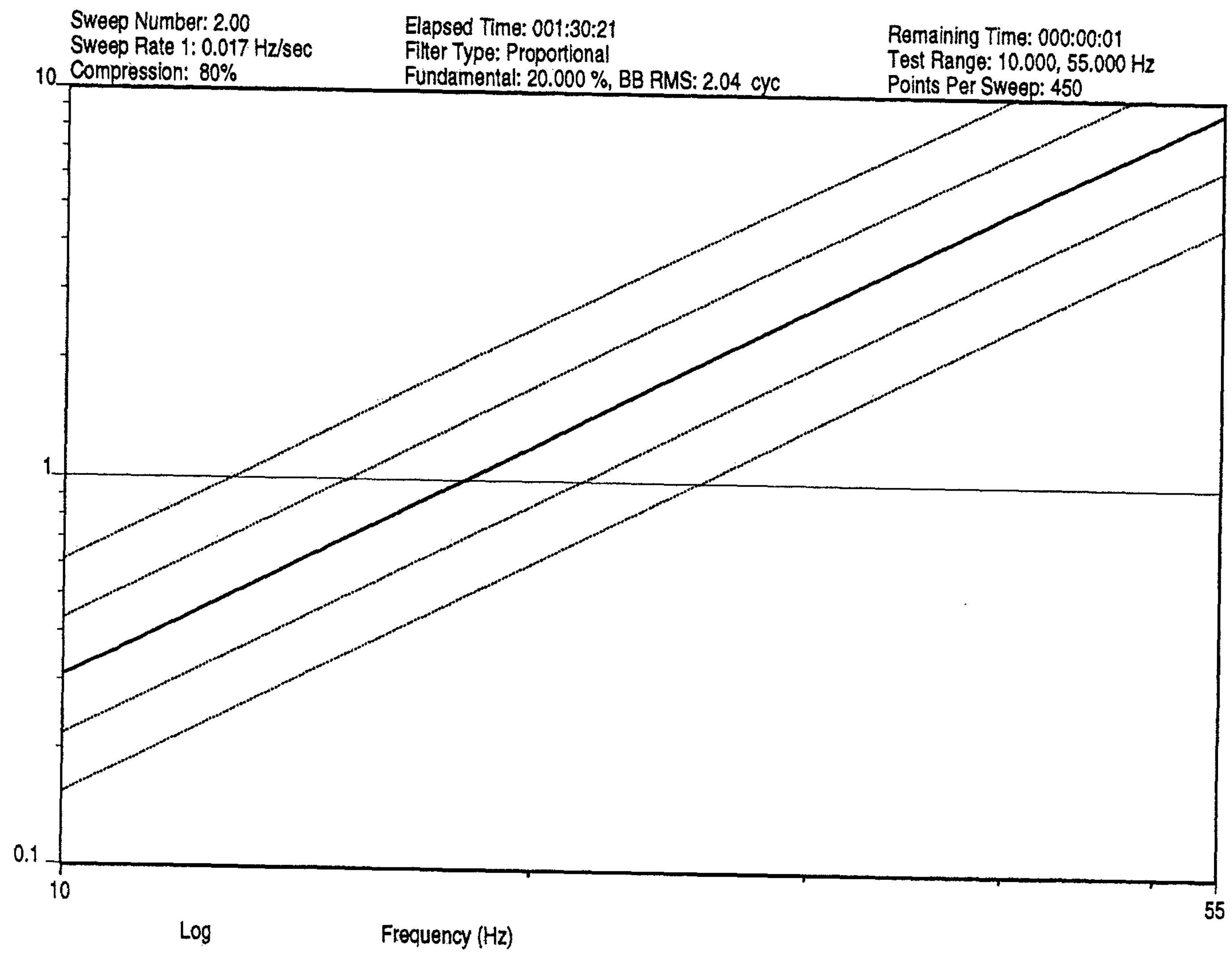
Elapsed Time: 001:30:21
Filter Type: Proportional
Fundamental: 20.000 %, BB RMS: 2.04 cyc

Remaining Time: 000:00:01
Test Range: 10.000, 55.000 Hz
Points Per Sweep: 450



17:55:56
Thu Jul 07 2005

NVE, Inc. Battery Charger, Smart Level 3 M/N X1EC001-13
Vertical Axis S/N 000002
Sine Data Review Name: 31645.001



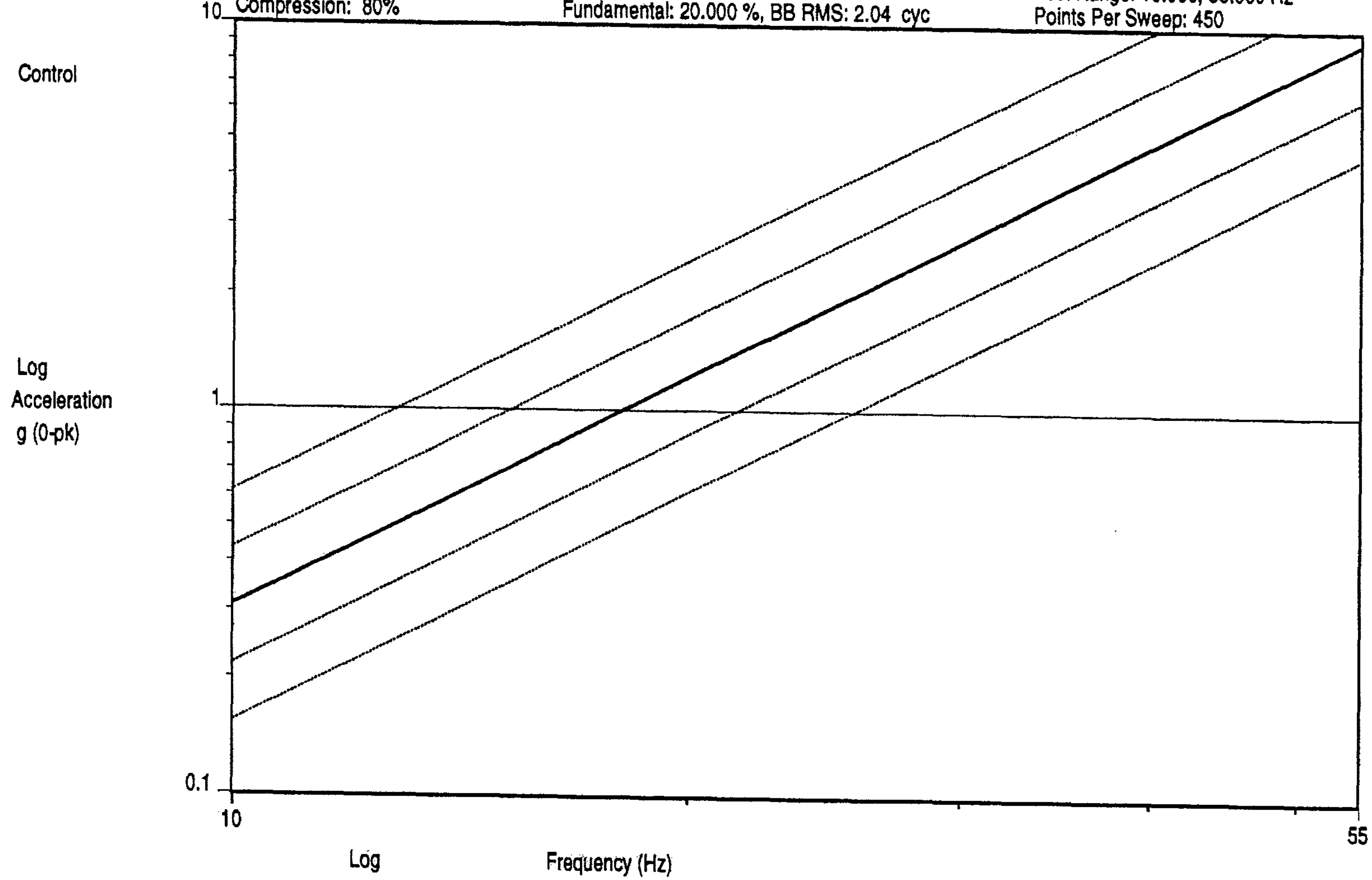
12:54:52
Fri Jul 08 2005

NVE, Inc. Battery Charger, Smart Level 3 M/N X1EC001-13
Longitudinal Axis S/N 000002
Sine Data Review Name: 31645.002

Sweep Number: 2.00
Sweep Rate 1: 0.017 Hz/sec
Compression: 80%

Elapsed Time: 001:30:21
Filter Type: Proportional
Fundamental: 20.000 %, BB RMS: 2.04 cyc

Remaining Time: 000:00:01
Test Range: 10.000, 55.000 Hz
Points Per Sweep: 450



15:23:28
Fri Jul 08 2005

NVE, Inc. Battery Charger, Smart Level 3 M/N X1EC001-13
Latitudinal Axis S/N 000002

Sine Data Review Name: 31645.003

APPENDIX E – LOOSE CARGO TEST

environ
LABORATORIES LLC

9725 GIRARD AVENUE SOUTH
MINNEAPOLIS, MINNESOTA 55431-2621

ENGINEERING REPORT NO. 31645-5

LOOSE CARGO TEST

for

NVE, INC.
11409 VALLEY VIEW ROAD
MINNEAPOLIS, MN 55344

PREPARED BY:	Denise I. Hart Denise I. Hart Technical Writer
	Tom P. Braun Tom P. Braun Test Engineer
	David M. Gillen David M. Gillen Vice President
APPROVED BY:	Charles W. Mapes Charles W. Mapes Project Engineer

REVISION HISTORY

Revision	Total Number of Pages	Date	Description
--	7	10 August 2005	Original

PREPARED FOR:	TEST DATES:	
NVE, INC. 11409 VALLEY VIEW ROAD MINNEAPOLIS, MN 55344 ATTN: Mr. Tom Norkunas	Start: Completion:	7/27/2005 7/27/2005
	ENVIRON TEST NO.:	31645-5
	PURCHASE ORDER NO.:	07741
	PURCHASE DATE:	6/9/2005

LOOSE CARGO TEST

1.0 ABSTRACT

1.1 Object

Subject the X1EC001-13 Smart Charger to a Loose Cargo Test in accordance with Smart Charger Phase II Requirements, Paragraph 2.5.

1.2 Conclusions

Visual examination of the exterior of the test unit and of the mechanical / electrical connectors revealed no change on completion of the test. Post-test functional checks to be performed by NVE, Inc.

2.0 UNIT(S) TESTED

MANUFACTURER:	NVE, INC.
DEVICE:	Smart Charger
MODEL/PART NO.:	X1EC001-13
SERIAL NO.:	000002

The results of this test apply only to the units identified in this Engineering Report by device identifier and model / part number, or serial number.

3.0 TEST REQUESTED

Subject the test unit to a Loose Cargo Test in accordance with Smart Charger Phase II Requirements, Paragraph 2.5, which references MIL-STD-810F, Paragraph 514.5, Procedure II.

The testing shall be conducted as follows:

1. The test unit shall be positioned in a cargo tester bed in its most likely shipping orientation. The impact walls and floor shall be made of wood. Conduct the first half of the test in this orientation.
2. Rotate the test bed and walls 90°.
3. Conduct the second half of the test in this orientation.

4.0 INSTRUMENTATION, PROCEDURE AND RESULTS

4.1 Instrumentation

All instrumentation is calibrated regularly by instruments directly traceable to the National Institute of Standards and Technology, and in accordance with MIL-I-45208A, ANSI/NCSL Z540-1-1994 and ISO/IEC 17025: 1999.

Equipment Number	Description	Manufacturer	Model Number	Last Calibration	Due Calibration	Range
390-006	Optical Tachometer	Cole Parmer	87303-00	3/23/2005	3/23/2006	6 to 30,000 RPM
400-036	Stopwatch	VWR International	61161-350	8/19/2004	8/21/2006	0 to 24 hours
Package Testor	L.A.B.	SNVMCTHG-5	N/A	N/A	100 to 450 RPM	Package Testor

4.2 Procedure

The Smart Charger was placed in a cargo tester with a plywood floor and wood walls to prevent the unit from turning. The tester was set for 1-inch displacement from peak to peak, with a speed of 5 Hz. The unit was tested for 30 minutes and then removed from the tester.

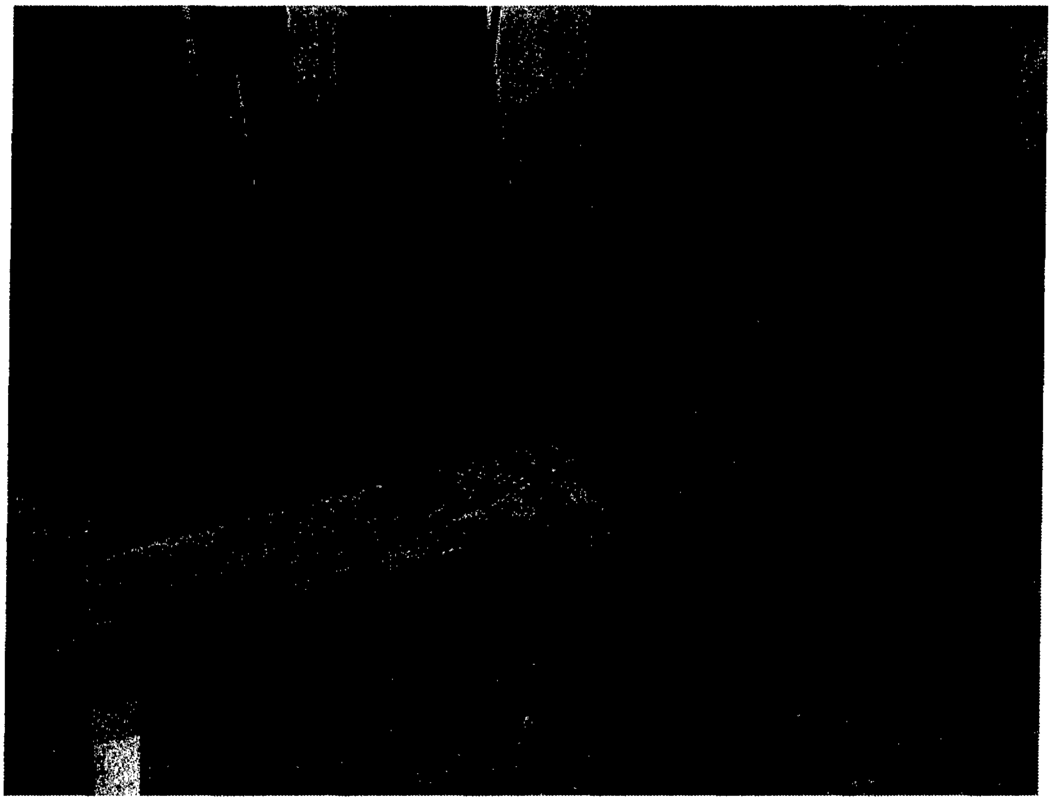
The test bed and walls were then rotated by 90°. The test unit was placed in the tester and the tester was activated. The unit was tested for an additional 30 minutes, for a total of 60 minutes.

Photograph No. 1 provides a view of the test unit and setup.

4.3 Results

Visual examination of the exterior of the test unit and of the mechanical / electrical connectors revealed no change on completion of the test. Post-test functional checks to be performed by NVE, Inc.

Refer to Figure No. 1 for a copy of the test data sheet.



Photograph No. 1: The test unit placed in the cargo tester.

environ Laboratories LLC
9725 Girard Avenue South
Minneapolis MN 55431

Page 1 of 1
Date 7-27-05
Job Number 31645-5

DATA SHEET

COMPANY: NVE, Inc.	
DEVICE: Battery Charger, SMART, Level 3	
MODEL NO. X1EC001-13	S/N: 000002
TEST: Loose Cargo Test	SPEC: MIL-STD-810F PARA: 514.5 Procedure II

Test unit placed in cargo tester with walls to prevent the unit from turning - plywood bed
Tester activated (1" displacement peak to peak) speed set at 5 Hz. Tested for 30 minutes.
Test bed & walls rotated by 90° Test unit placed in tester. Tester activated. Tested for 30 min.

Visual Examination of the exterior of the unit reveals no change. No change in mechanical/elec. connectors
Operational Examination - No test apparatus supplied - No charge indicated when charge status button pressed. Any functional checks will have to be done @ NVE.

400-036 503-133 390-006

Test Performed By: TS

QAF 5.3.1 Rev A ISSUED BY: MICHAEL S. WOOD 5/26/2000

Figure No. 1: Loose Cargo Test Data Sheet